AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

<u>Topic 1.3 Cell Membranes and Transport</u> – Page 1

1.3 Cell Membranes and Transport – from your syllabus

(a) the principal components of the plasma membrane and understand the fluid-mosaic model

(b) the factors affecting permeability of the plasma membrane

(c) the following transport mechanisms: diffusion and factors affecting the rate of diffusion; osmosis and water potential; pinocytosis; facilitated diffusion; phagocytosis; secretion (exocytosis); active transport and the influence of cyanide

SPECIFIED PRACTICAL WORK

- Determination of water potential by measuring changes in mass or length
- Determination of solute potential by measuring the degree of incipient plasmolysis
- Investigation into the permeability of cell membranes using beetroot

I. <u>Cell Membrane Structure</u>

		Completed
1.	Read and Compete the Following: • Rowlands p36-37 • Toole p • Handout 1.3a Membrane Structure • Handout 1.3b Molecules in the Plasmamembrane	
2.	Go through the PowerPoint 'Cell Membrane 1' and 'Cell Membrane 2'.	
3.	Complete the task and answer the questions on Handout 1.3a	

End of topic check list for CELL MEMBRANES & TRANSPORT
Tick as appropriate:
RED : I do not know about this
AMBER: I have heard about this but have not learned this yet. I am unsure on this.
GREEN: I have heard about this and I have learned this. I am confident about this.

Topic	RED	AMBER	GREEN
1. All cells are surrounded by a membrane which may be called the cell surface membrane or the plasma membrane.			
2. The cell membrane appears under the electron microscope as a double line.			
3. The usual distance across the cell membrane under the electron microscope is 7-8 nm.			
4. The principal biochemical constituents of the cell membrane are protein and phospholipid.			
5. The phospholipid molecules are arranged as a bilayer with hydrophilic heads and hydrophobic tails.			
6. Some proteins lie on the surface of the bilayer and some are partly embedded, whilst others extend completely across it.			
7. This model is referred to as the 'fluid mosaic' model because the components are free to move with respect to each other.			
8. You should be able to draw a simple diagram to illustrate the fluid mosaic model including the labels: phospholipid bilayer, proteins, hydrophilic pores/channels (in some proteins), and glycoproteins.			
9. The major functions of the cell membrane include taking up nutrients and other requirements; secreting chemicals; cell recognition.			
10. The cell surface membrane is selectively permeable to water and some solutes.			
11. You should be able to interpret the results of an investigation into factors, heat and organic solvents, affecting the permeability of a cell membrane.			
12. Lipid-soluble substances can move through the cell membrane more easily than water-soluble substances, which use temporary protein channels.			
13. You should be able to define the term 'diffusion'. It is the movement of molecules or ions from a region of high concentration to one of low concentration.			
14. The rate of diffusion across the membrane depends on: the concentration gradient, temperature, size of the molecule, lipid solubility.			
15. You should be able to define the term 'osmosis'. It is a particular form of diffusion in which water molecules move down a water potential gradient through a selectively permeable membrane.			
16. Water potential is the potential for water to move out of a solution by osmosis. It has the symbol ψ (psi). Pure water has the highest water potential, given the value zero. All solutions have a lower potential than water because they have a lower proportion of water molecules, therefore ψ_s always has a negative value.			
17. In a plant cell the water potential is the sum of two factors: the solute potential (ψ_s) which is the effect of			

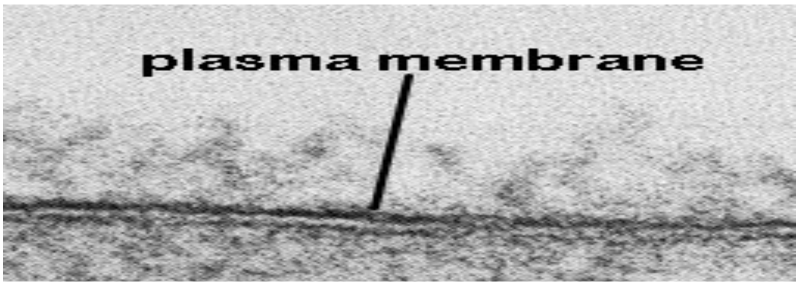
solutes lowering the water potential of the cell sap (negative value) and ψ_p which is the opposite pressure provided by the cell wall and is usually positive ($\psi_{cell} = \psi_s + \psi_p$).			
18. You should be able to use a given equation and interpret data.			
19. When a cell loses water it shrinks; the cytoplasm of a plant cell will draw away from the cell wall and the cell is described as being plasmolysed.			
20. A cell will gain water if placed in a hypotonic solution; an animal cell will burst but a plant cell will continue to take in water until prevented by the opposing wall pressure when the cell is described as being fully turgid.			
21. Facilitated diffusion allows rapid exchange due to substances being helped across the membrane by special carriers. ATP is not needed.			
22. Phagocytosis is where a large particle may enter the cell, become enclosed by a membrane to form a vesicle and be transported through the cytoplasm.			
23. You should be able to draw a diagram to illustrate phagocytosis.			
24. Secretion or exocytosis refers to substances leaving the cell after being transported through the cytoplasm in a vesicle.			
25. The cell membrane is continually having portions removed or added to it through phagocytosis and secretion.			
26. Pinocytosis is the entry of liquid by the same mechanism as phagocytosis.			
27. Active transport requires energy from respiration and takes place against a concentration gradient so allowing a solute to be accumulated within a cell.			
28. Active transport will not take place in the presence of a respiratory inhibitor such as cyanide.			
29. A solute may be taken across a cell membrane by a special carrier molecule.			

How Membranes are organised

We cannot live without them

To stay alive, all living things need membranes. Membranes are barriers that give cells their outer boundaries (**plasma membrane OR cell surface membrane)** and their inner compartments (**organelles**). Being selectively permeable membranes are able to control the movement of substance into and out of cells, regulating the composition of fluid within individual cells. Membranes control the flow of information between cells either by recognizing signal molecules received from other cells, or by sending chemical or electrical signals to other cells. Biological membranes are therefore, more than just an inert barrier or covering they play an active part in the life of a cell.

The plasma membrane and membranes found within cells is only about 7-10nm in diameter.



Three membrane components
Biological membranes are made of three major components: **lipids, proteins** and **carbohydrates**. All membranes have a common general structure in which two layered sheets of lipid molecules have proteins embedded in them. The structure is highly fluid and most of the lipid and protein molecules can move about in the plane of the membrane. The lipid and protein molecules are held together mainly by non-covalent interactions. Carbohydrates are attached by covalent bonds to some of the lipid and protein molecules, they are found on one side of the membrane only: for example, on the outer surface of the plasma membrane only.

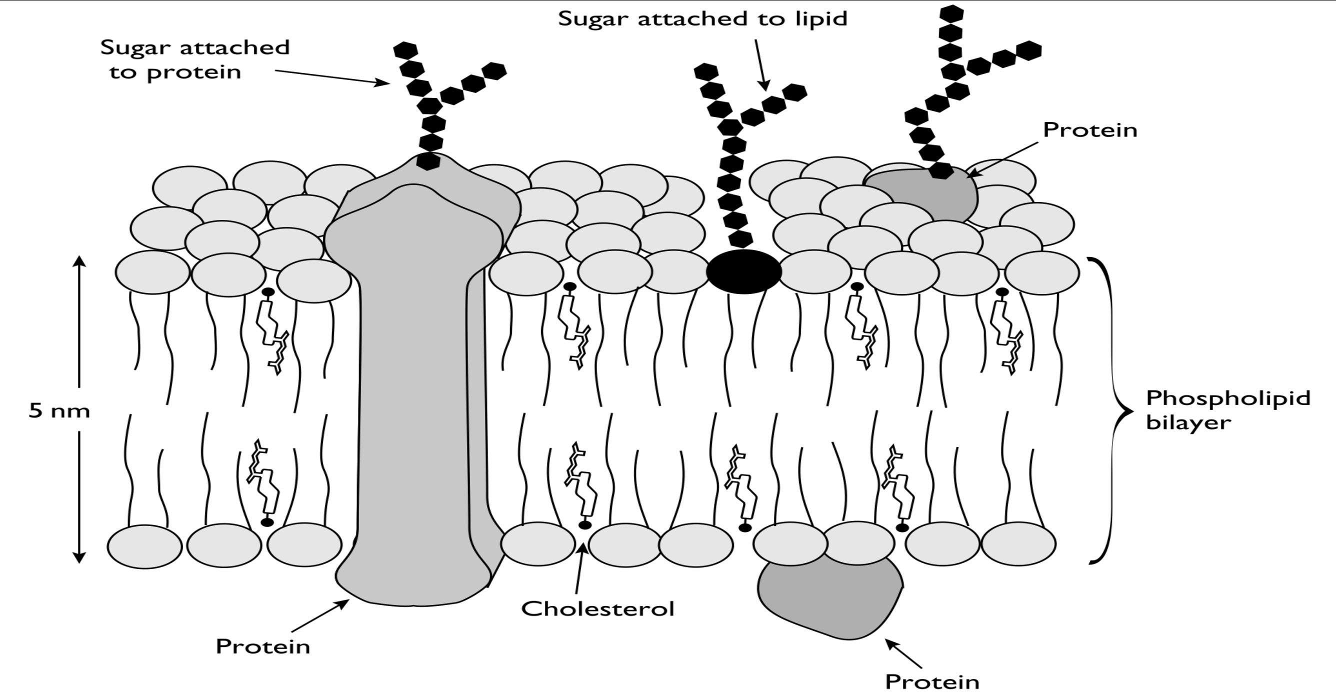
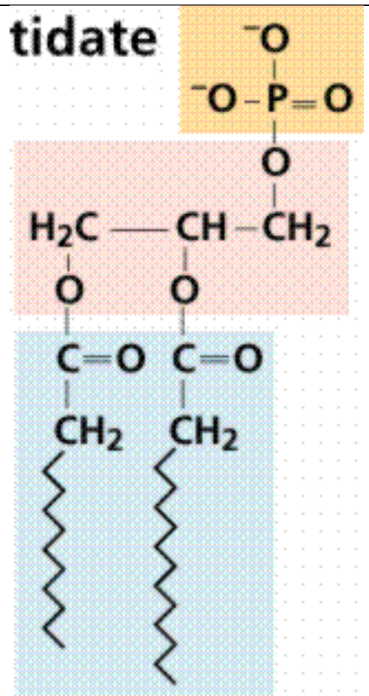


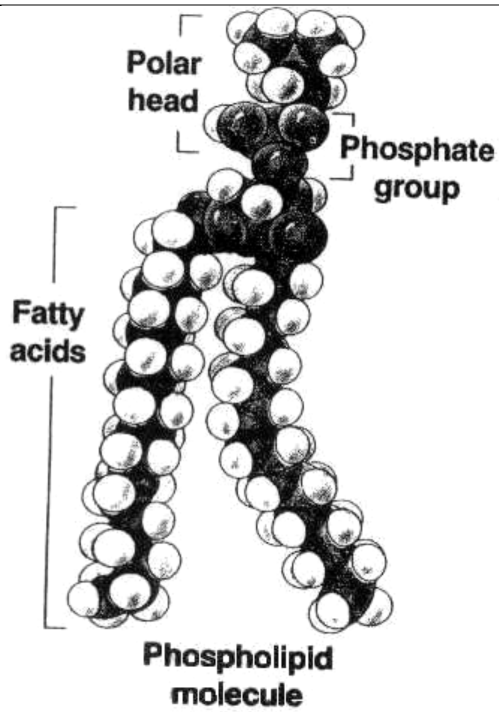
Figure 1. Diagrammatic representation of a biological membrane.

Three types of lipid

Lipids are biologically important substances that are insoluble in water but are soluble in organic solvents such as propanone (acetone), ethanol etc. There are three major types of lipid found in biological membranes: **phospholipids**, **glycolipids** and **cholesterol**. They each play a different role in the membrane.

Phospholipids are important components of all membranes found in cells. Phospholipids are made up of two fatty acid chains joined to a glycerol molecule and a polar phosphate containing head. The head is **hydrophilic** (water loving) and the tail is **hydrophobic** (water hating). A molecule with hydrophilic and hydrophobic properties is termed **amphipathic**. The heads of the phospholipids are often termed **polar** and the fatty acids **non-polar**.

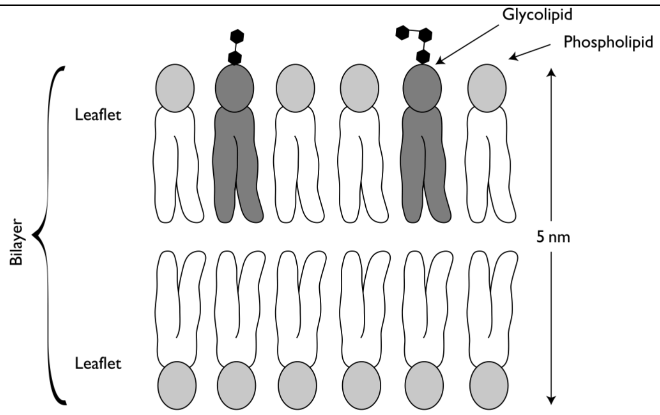




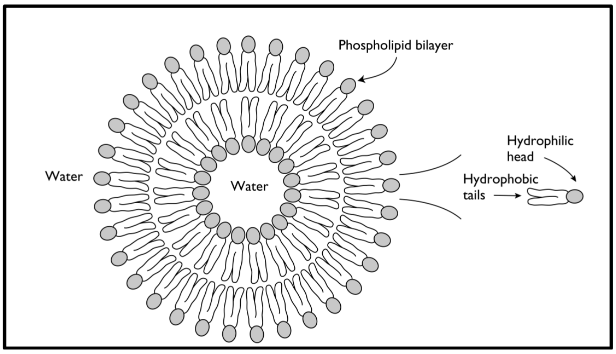
Glycolipids contain carbohydrates

Glycolipids differ from phospholipids in that glycolipids have a sugar such as glucose, or galactose, instead of the phosphate containing head. In all cases, glycolipids are found on the outer surface of the plasma membrane with their sugars exposed at the cell surface.

Phospholipids and glycolipids each have a **hydrophilic head** and two **hydrophobic tails**. If submerged in water, these molecules will spontaneously associate to form **bilayers**, with their hydrophobic tails sandwiched between the hydrophilic heads.

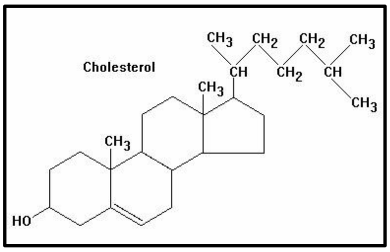


Bilayers form because the hydrocarbon tails have a strong tendency to stay away from water, and are 'squeezed together' by water molecules. Such bilayers will close in on themselves to form sealed compartments called **liposomes**, these eliminate the edges where tails would be in contact with water. Liposomes are useful model membranes for research and may also be used to deliver drugs to particular organs of the body. Liposomes are absorbed by many cells fusion with the plasma membrane.



Cholesterol

Cholesterol is a molecule that is also found in cell membranes. It is a type of lipid but is not a fat or oil. It instead belongs to a group of chemicals called steroids. The majority of the cholesterol molecule is hydrophobic and so it attracted to the fatty acids of the phospholipids in the membrane. However the OH group on the end is hydrophilic, and so orientates itself nearer the hydrophilic phosphate heads.

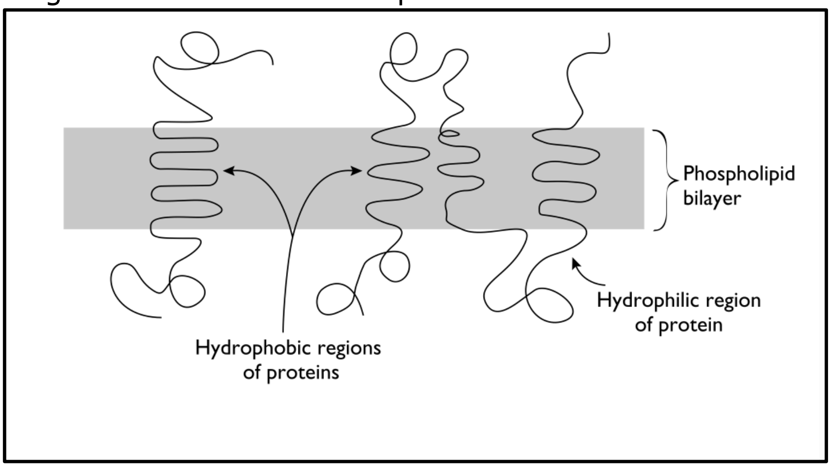


Its role in the membranes is to regulate the fluidity of the membrane, act as a fluidity buffer. If membranes were too fluid, then the amount of control over what entered the cell would be lost. Conversely if the membranes were too rigid, then the movement of cells, the formation of vesicles and the processes of endocytosis and exocytosis would not be able to occur.

Membrane proteins

Many of the specific functions of membranes are carried out by proteins. Accordingly, the amount and type of protein found within a membrane varies from cell to cell and organelle to organelle. The more active a membrane is in metabolism, the more protein it will contain.

There are several ways in which proteins are associated with lipid bilayers to form functional membranes. Some proteins extend across the phospholipid bilayer and are often referred to as intrinsic, integral or transmembrane proteins.

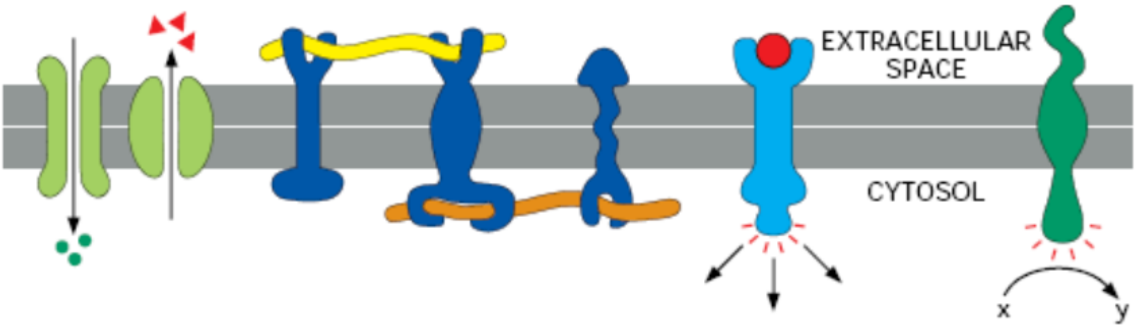


Other proteins lie on the surface and are only partly embedded in the membrane. These are referred to as extrinsic or peripheral proteins.

The function of membranes is to provide a barrier between the inside and outside of a cell or an organelle. Of course, certain substances will need to be allowed into the interior of the structure, and certain substances will need to be allowed out of the structure. This is one of the functions of the proteins in the membrane. There are other functions that the proteins perform as well. Some proteins:

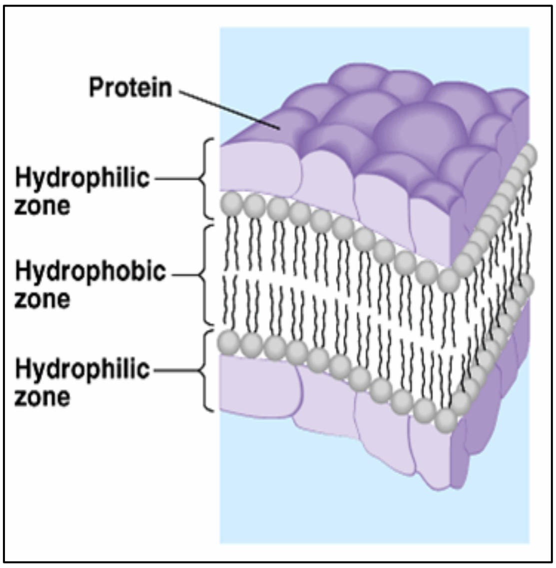
- ✓ provide channels for passive transport of materials.
- ✓ act as active transport pumps to move substances
- ✓ act as hormone binding sites (hormone receptors)
- ✓ are immobilised (i.e. fixed position) enzymes
- ✓ help with cell adhesion forming junctions between neighbouring cells.

Label the following diagram with the function of the proteins shown.

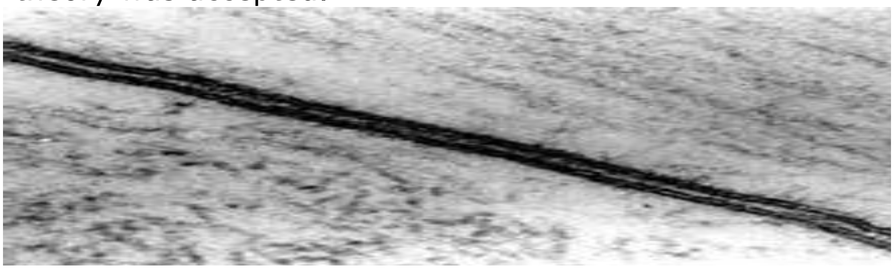


Evidence for the Structure of the Cell Membrane

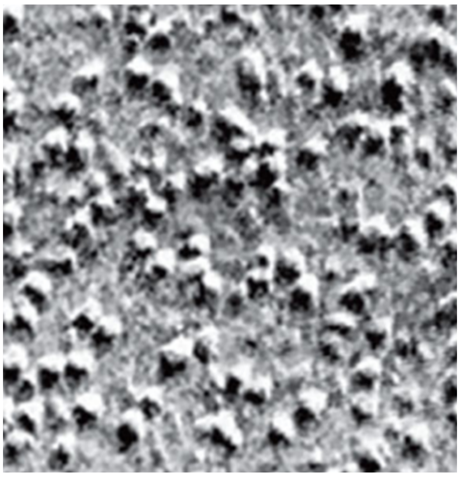
Two scientists, Gorter and Grendel extracted phospholipid molecules from plasma membranes in the 1920s. However they encountered a problem. When they calculated the area that the phospholipids occupied, they found that it measured twice as much as it should have. They deduced that the phospholipids were not arranged in a monolayer, but a bilayer. The bilayer model fitted, but it didn't explain the fact that scientists had also extracted protein molecules from membranes.



In 1930 Davson and Danielli proposed a model (right) that incorporated the proteins.
They thought that the proteins were located above and below the phospholipid bilayer, like a sandwich. This theory was accepted and in the 1950s, when electron microscopy was used to look at the membranes (below), the membranes did appear as two dark lines with a lighter band in the middle. And so this theory was accepted.

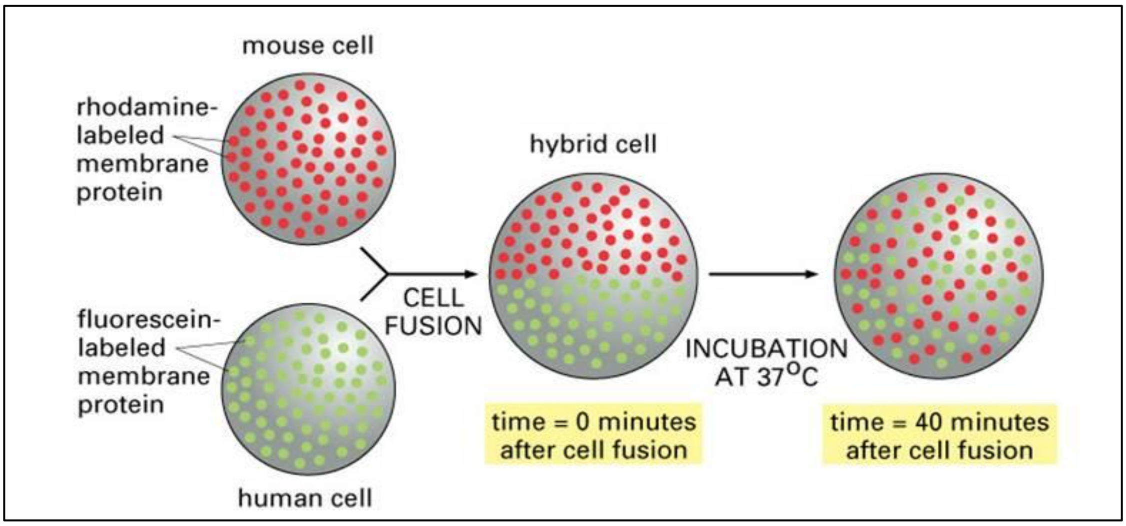


This model was a good attempt at elucidating the structure of the membranes in cells, but was unfortunately incorrect. For 30 years scientists accepted the Davson-Danielli model and even other studies, e.g. X-ray diffraction seemed to add evidence to their theory. However not all evidence did fit with the model.



- ✓ Freeze-etched electron micrographs: This technique involves reducing the cells temperature to freezing very quickly and fracturing the cells. The fractures appear around the weakest points of the cell including the centre of membranes. It appeared that tiny globular structures were found in the centre of the membranes, indicating trans-membrane proteins.

- ✓ Antibody tagging: This involved adding red and green tagged antibodies to the proteins in the membrane. Cells with red tags were fused with cells with green tags. After a period of time it was observed that both the red and green tags were mixed throughout the membranes of the fused cells. This led to the idea that proteins were not in a fixed position but free to move throughout the membrane.



- ✓ The structure of the proteins: When these were examined, it was found that the proteins in the membrane were not the type of proteins that would form a continuous layer. This led to the idea that proteins have specific functions in the membrane.

With all of these extra pieces of evidence, Singer and Nicolson hypothesised a new model of the membrane structure. They thought that instead of the proteins being a layer above and below the phospholipid bilayer that they instead were embedded in the membrane. Some proteins were attached to the outer or inner side of the membrane (peripheral proteins) and others were embedded through the membrane with areas sticking out of the top and bottom (integral proteins). They also thought that the proteins were not in a fixed position but free to move (fluid), and that these proteins looked like tiles in a mosaic. The Singer-Nicolson 'fluid mosaic' model of membranes is still the leading model for the structure of membranes.

Tasks

Draw a fully labelled diagram to illustrate the fluid mosaic model including: the phospholipid bilayer, proteins, (extrinsic and intrinsic), hydrophilic pores/channels (in some proteins) and glycoproteins.

1. Why is the term 'fluid mosaic' used to describe cell membranes?
2. The framework for a membrane is provided by a phospholipid bilayer. Explain why such bilayers are stable structures.
3. How are proteins arranged in the membrane?
4. Where and in what form are carbohydrates found in a membrane?
5. What effect do cholesterol molecules have in the membrane?
6. Cell membranes are described as 'partially permeable'
    a. What does the term partially permeable mean?
    b. What types of molecule will not be able to pass across the phospholipid bilayer?
    c. What alternative routes might these molecules take?
7. State the roles of the following molecules in a membrane:
    a. proteins
    b. glycolipids
    c. glycoproteins

Answer the following multiple-choice questions:

1) Which of the following is **not** a function performed by a membrane protein?

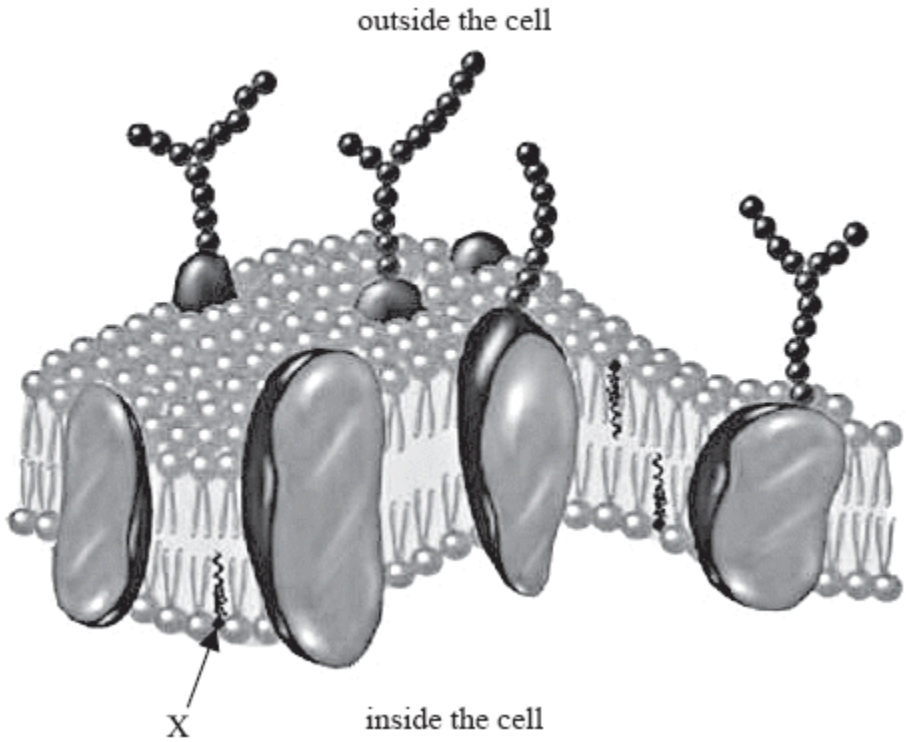
A. Hormone binding sites

B. Cell adhesion

C. Enzyme synthesis

D. Pumps for active transport

2) The diagram below shows a plasma membrane. What is molecule X?



A. Cholesterol

B. Peripheral protein

C. Glycoprotein

D. Polar amino acid

3) What is the function of the plasma membrane around a bacterium?

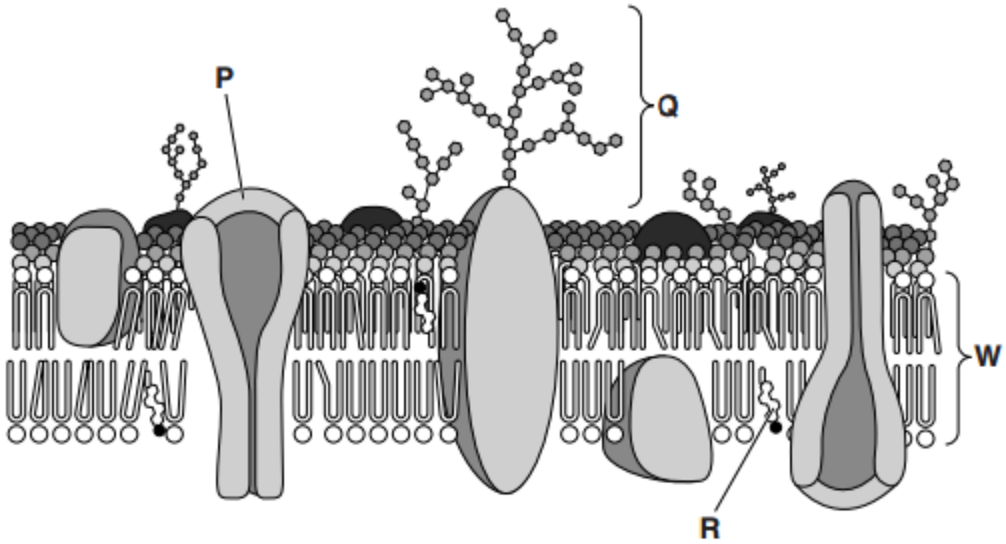
A. To produce ADP

B. To form the only protective layer preventing damage from outside

C. To control entry and exit of substances

D. To synthesize proteins

4) The diagram shows a section of a cell surface membrane.



(a) State the functions of structures P, Q and R.

P

____

Q

____

R

____

(b) Which of these is an appropriate width of the membrane (W)?

17.0 μm   1.7 μm   0.7 μm   70.0 nm   17.0 nm   7.0 nm   0.7 nm

Molecules in the plasmamembrane

Allow:

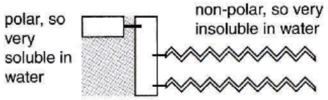
- recognition;
- signalling;
- adhesion;
- fluidity.

Fibrous protein is **glycosylated** and important in cell identification e.g. **glycophorin** in the membrane of erythrocytes determines blood groups.

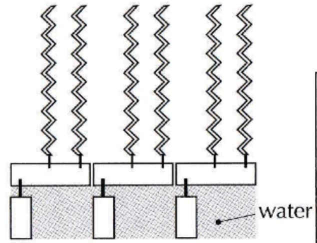
Glycocalyx composed of **oligosaccharides** is important in recognition – cell-cell contacts of this type may regulate cell growth, division and development. The glycocalyx is added to membrane components synthesised in the endoplasmic reticulum at the Golgi complex before incorporation into the membrane.

Phospholipid bilayer is impermeable to water-soluble, charged solutes and is a barrier between adjacent aqueous environments.

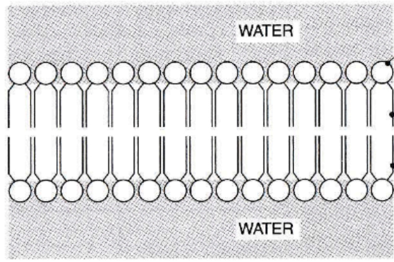
Because of the different solubility properties of the two ends of **phospholipid** molecules …

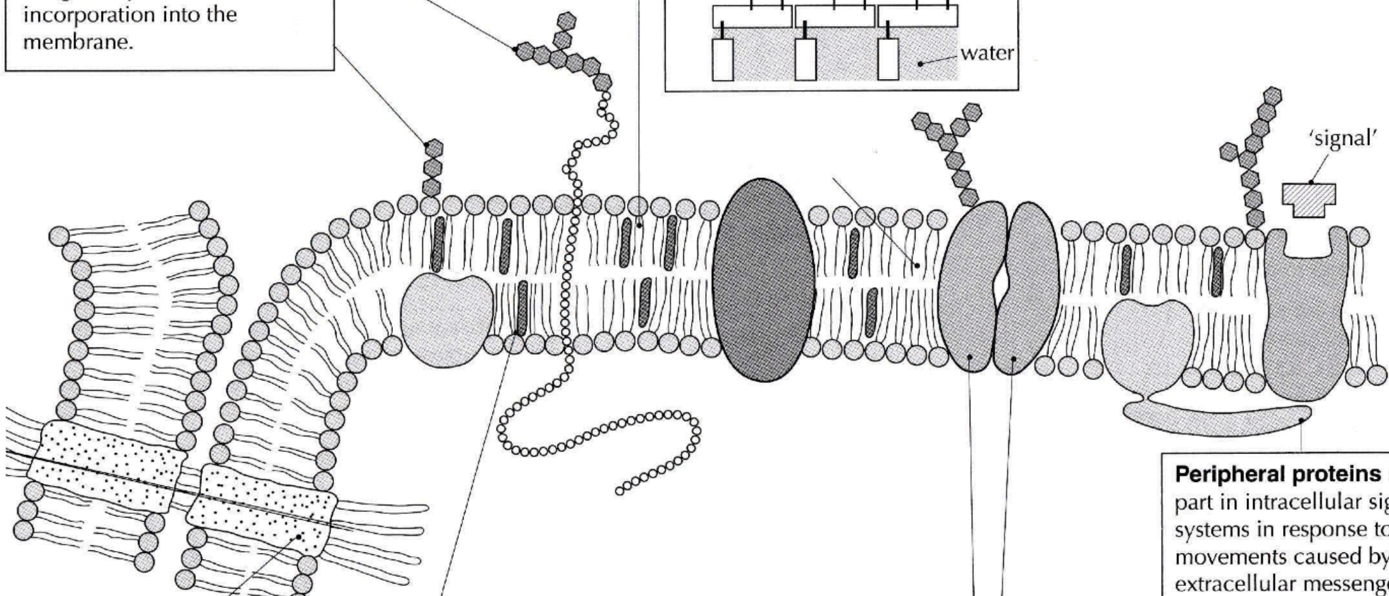


… these molecules form a layer at a water surface.



and a **phospholipid bilayer** can act as a barrier between two aqueous (watery) environments.





Receptor proteins have a specific shape which allows them to bind to other molecules with a complementary shape. The binding can set off a reaction in the cell, for example:

- the hormone adrenaline can bind to the correct receptor and set off reactions leading to the release of glucose inside the cell
- the neurotransmitter acetylcholine can bind to the postsynaptic membrane and cause an inflow of sodium ions as an impulse is conducted
- growth substances may bind and control nuclear division in cells within a tissue.

These messengers are part of a **signalling** system which makes sure that cells perform their functions to the correct extent and at the right time.

Cell adhesion proteins firmly attach adjacent cells to one another, this is particularly important in epithelia. These proteins also serve as internal anchorage points for protein tubules of the cytoskeleton.

Cholesterol acts as a fluidity buffer – at low temperatures it prevents crystallisation of hydrocarbon tails and at high temperatures it prevents excessive fatty acid mobility which might otherwise affect membrane permeability.

Pore proteins provide channels for polar molecules:

- between the cell and its aqueous environment;
- between the cytoplasm of adjacent cells.

Peripheral proteins may play a part in intracellular signalling systems in response to protein movements caused by binding to extracellular messengers. The enzyme **adenyl cyclase** is closely associated with the membrane's inner surface and catalyses the conversion.

ATP ⟶ cyclic AMP

as a **second messenger** following the binding of some hormones, e.g. adrenaline.